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RAILWAY BUILDING IN CAPE COLONY.

By E. R. LEWIS, B. S.

(Class of 1890.)

THE methods of railway surveying and construction in Cape Colony, which differ so widely from American practice, have been modeled after the British system. They have however been greatly modified by local influences. This fact renders necessary a short explanation of the geographical, geological, topographical and climatic conditions; together with some few governmental peculiarities, which have been influential in producing the resultant existing practices in railway circles.

Cape Colony, or the Colony of the Cape of Good Hope, is that dependency of Great Britain which occupies the southernmost portion of the continent of Africa. It is bounded on the north by Great Namaqualand and the Kalahari Desert; on the east by the Transvaal, the Orange River Colony and Natal; on the south by the Indian Ocean; and on the west by the Atlantic Ocean. It lies between latitudes 28° to 35° south and between longitudes 17° and 30° east from Greenwich. The latitude of Capetown corresponds closely with that of Buenos Ayres in Argentine.

The geological features merit volumes of explanation, but it is sufficient here to say that some great convulsion of the whole sub-continent in ages past has resulted in a squeezing together of the coast strata from north and south so that scarcely a rock seems to have been left in a horizontal position. Strata appear, when exposed, in fantastic waves and curves, or at divers degrees of slant from the horizontal.

Different varieties of sandstone from those just forming to quartz outcrops are continually encountered in railway work.

A blue, slaty shale, which weathers badly, is the frequent outcrop of rock which is very difficult to handle. The soil is thin, gravelly and sandy, often mixed with a yellow clay.

South Africa has been described as resembling in formation an inverted saucer; the successive low ranges of mountains rising from the coast line to the high veldt level representing the saucer's rim; while the great inland plateau or Karroo, varying in elevation from 3000 to 5000 feet, represents the bottom of the saucer. Cape Colony possesses some 1200 miles of coast line, one-third forming part of the eastern limit of the Atlantic Ocean and the remaining two-thirds the coast line of the Indian Ocean.

The Antarctic Ocean current, following northward along the west coast of Cape Colony, lends a beneficent coolness to the atmosphere, making the climate mild enough, although so close to the tropics, to be habitable to the white races. In the higher altitudes, the climate is mild and uniform. The two seasons, rainy and dry, are clearly defined and very regular. The sun in these latitudes exerts a great influence, its rising and setting marking sharply the limits of the day's heat. As soon as the sun has set, the atmosphere becomes suddenly cool and delightful, even in the hottest weather.

The Karroo is essentially a grazing country, and its dry, invigorating air makes it an asylum for consumptives. The rainy season begins with mid April and ends with September, during which season the principal crops;—tobacco, wheat, oats, barley, rye, millet, potatoes and corn are grown. Heavy downpours of rain occur during the rainy season about three days of each week. The river beds, dry through the summer season, become sluice ways of raging torrents. So furious are the rains and so easily cut is the parched and powdery soil that the streams soon find the bed rock, while the banks become nearly perpendicular cliffs. Irrigation by conservation of water supply or by dams and diverting canals becomes thus a most difficult problem, and has remained to the present time largely unsolved.

Out of its total area of 221,311 square miles (four times the

area of Iowa) Cape Colony has disposed of some 90,000,000 acres of land. The average farm of the "Pastoral Boer" of Cape Colony is from 2,000 to 4,000 morgen or 2.1 times that number of acres. This land generally resembles that which was formerly known as the Great American Desert;—more especially does it resemble the better parts of that "desert" as Eastern Colorado and Western Kansas. The sparse growth of rhinoceri bush of the Karroo lands closely corresponds to the sage brush of our western plains. The average summer temperature of the ground in Cape Colony is $+70^{\circ}$ F. Nevertheless light frosts and light snow falls are not unknown on the Karroo during the wet seasons, while the southern mountain peaks almost invariably show white at some time during the winter.

The population of Cape Colony has been variously estimated at from 2,000,000 to 2,500,000 during the past year. The taking of a census is now in progress. The principal cities are Capetown and suburbs, population 90,000; Kimberly 30,000; Port Elizabeth, 28,000; Grahamstown, 10,000; East London, Paarl and King William's Town, 8,000 each; and Graaf Reniet, Uitenhage, Worcester, Cradock, Outshoorn, and Queenstown about 5,000 each. Of these cities, Capetown, Port Elizabeth and East London are the chief coast ports.

Cape Town, the metropolis and seat of government is situated on Table Bay, twenty-one miles from Cape Point, the southernmost point of Cape Peninsula. Cape Town is a most cosmopolitan city. There is still to be seen, in fairly good preservation, the chain of old Dutch forts and block houses which marked the military limits of the Cape Town of 1792. On the principal streets today, natives of the British Isles, and of all Europe, elbow their way through crowds of Australians, Americans, Malays, Hindus, and native South Africans.

Cape Colony is ruled by two houses of parliament, composed of members elected from and by the voters of the several colonial constituencies, and presided over by a Prime

Minister chosen by the party representing the majority, in conjunction with a King's Commissioner, who is the Colonial Governor and the representative of the Imperial British government. The ministry of the Cape parliament is composed of six members chosen from the members of parliament by the Prime Minister. One of the most, if not the most, important of the ministerial portfolios is that of the Commissioner of Public Works.

Under the direction of this official exists the rapidly growing system of the Cape Government Railways, which is further officered by the usual staff of General Manager, Chief Engineer, and so forth. Government ownership and operation of railways has proven a necessity and a boon to this colony of sparse population and vast area. Without the fostering care and wise expenditures of the British government, South Africa would still be the land of slavery and the trek-ox, while Kimberley, Jagersfontein and Johannesburg would in all probability never have given up the full secrets of their untold wealth of precious stones and fine gold.

At the present time, this railway system, (although still in its infancy and burdened with many non-paying branch lines, built over miles of desert country, to succour small, isolated productive districts) yields a very considerable amount of revenue to the government.

Cape Railways comprise the Eastern, Midland and Western Divisions, in all about 2,500 miles of line in operation, with some 300 to 500 miles in course of construction. These three divisions are really three main lines from the coast ports of Cape Town, Port Elizabeth and East London inland to the northern confines of the colony, together with branches to different inland markets. A well equipped suburban line from Cape Town to the naval station, Simonstown, distant twenty-one miles, is a rich and paying asset of the Western division.

Parts of a coast line, long since projected, to connect the seaboard cities, are also being operated, while the main line from Cape Town to Burnways is a large factor in the scheme of connecting the former city by rail with Cairo, Egypt.

The proposition for a new line of railway having been made, argued and voted in parliament, sufficient funds for a flying survey and for a second and closer reconnaissance are appropriated, according to circumstances and to obstacles anticipated.

The flying survey is ordinarily made by an engineer and one assistant, using any convenient method for transporting themselves, luggage and their instruments. The Cape Cart is the usual conveyance. The instruments used are the aneroid barometer, Abney level, tacheometer and box sextant. Distances, ruling grade points and elevations, angles and general features of the country traversed are noted in an exhaustive report, while the proposed line is marked on the government maps of the districts involved.

A second or even a third reconnaissance may be ordered and reported. When parliament has finally settled upon the route and has appropriated funds for the permanent location of the line, engineer corps are sent into the field for that purpose.

Three engineers, each fully competent in all branches of railway work, take charge of each district of a line 40 miles or more in length. For the purposes of preliminary survey and location, one very complete camp equipment is issued to each district. This equipment includes eight tents, portable furniture, necessary tools and stationery, a Cape Cart and team, saddle horses, saddles, bridles, and so forth. Engineers furnish their own field and draughting instruments. Each engineer is empowered to hire, within reasonable limits, the laborers necessary to his work.

The old method of running trial lines of a preliminary nature, of simply "hunting routes" by cutting and trying, has been pursued in times gone by and is still occasionally resorted to in Cape Colony. But within the last decade the incredible ease with which engineers cut out expensive work and halve the estimates made under the old regime, has brought into prominence the European system of tacheometry, and the invaluable aid of that wonderful, though ancient, creation of mechanical simplicity and despatch, the slide rule.

While it is not my purpose nor privilege here to set forth in detail the practice of tacheometry, yet I cannot resist emphasizing the importance to every young engineer of a thorough insight and mastery of this system of preliminary survey; and of a knowledge of its wonderful results as compared to the old lath sticking and slope board process.

Given a competent corps and good instruments, notes may be taken during every day of eight hours, from which a contour map (accurate to at least .25 of a foot) of a strip of open country however difficult, at least a mile long by three-fourths of a mile wide, if necessary.

These notes, once taken, suffice for all purposes until the line is permanently staked out. No resurveys, no cutting and trying. The information taken admits of the plotting on the contour maps of the very best line of railway, even to the location of curve ends to within a few inches. Practically no room is left for improvement to the first line, neither reduction of grades, nor flattening of curves, nor retracing of route. Has the profession made any greater stride within its history? It is only to be deplored that this modern method has been so scantily recognized in the United States.

Each member of the party must be specially and thoroughly trained to his work. Three engineers are necessary at the instrument, which may be either a tacheometer or a serviceable transit theodolite in good adjustment. One engineer manipulates the instrument, reading stadia distances, horizontal angles and vertical angles to each point observed, in reference to given fore sights and back sites called instrument stations. The second engineer "books" the information, while the third places (by means of motions with different colored flags) the three to six rodmen at points of vantage. In this way the whole corps is kept constantly, absorbedly and systematically at work. Head and rear flagmen are employed, as well as the necessary axemen. The usual corps consists of three engineers and ten negro laborers.

There is no more gratifying occupation than the above, especially in consideration of the accuracy which gives the

engineer a sense of professional pride and triumph when his calculations check out in the final locations, and ever after, so long as maintenance engineers have cause to retrace his work. Such accuracy is the very essence of the profession, as applied to this order of work.

It is over very difficult ground that the tacheometer is of greatest utility. If along the side of a shelving and wooded cliff forming one side of a river gorge, and inaccessible for purposes of continuous chaining and levelling, the tacheometer may be set up at convenient points of observation on the opposite shore, while the rodmen pick their way to points among the rocks as directed. The timber can be felled sufficiently with comparatively light work by the axemen to admit of the sights being taken.

In Cape Colonial practice, after the line has been located in the field, a permanent plan and section, or profile, is made on continuous mounted draughting paper, the plan being above its corresponding section. The information on both plan and section is very complete. In the plan, every curve is carefully plotted by coördinates; curve-end chainages and lengths of tangents are marked; degrees of curvatures, quarter mile chainages and all topography, as farm beacons, boundary lines, buildings, plowed and cultivated lands, contours when necessary, bridges, road crossings, station buildings, water tanks, fences, telegraph and siding are clearly noted.

On the section too, the ground line, grade line, chainage, curve notes, bench marks, culverts, pipes, cattle passes, cattle guards and columns of figures representing cuts and fills, ground and grade elevations and earth work quantities are written clearly.

The surveyor's sixty-six feet chain of one hundred links is used in measuring, or more often a steel band similarly divided. A stake $1\frac{1}{2}$ inches square and from 6 to 8 inches long and painted red, is driven flush with the ground surface at each chain's length on the center line. Three such pegs mark each curve end, the center peg being the hub with tack marking

the tangent point, the outer pegs each one foot from the hub at right angles to the center line, and planted with their tops slanting away from the center peg. Curvature is expressed in radial terms. Thus, an 80 chain curve is a curve whose radius is 80 chains, or one mile in length. Offsets are for chords of 66 feet or 1 chain in length. Intersection points, chord points and bench mark guard pegs are painted white. Reverse curves are not allowed and no two curves must have their adjacent ends less than 2 chains apart, unless they be compounded. The maximum curve and grade vary of course with the nature of the country traversed. In ordinary country the 7 chain curve, compensated on gradients on a 1 in 70 grade, mark the limits worked to.

Since the gauge adopted by the Cape government is 3' 6"; and the parliamentary policy is to economize in first cost; and since there is absolutely no competition, and time and length of line are secondary considerations, therefore the Cape Colony Railways are located "on the grass roots" or following as closely as possibly the contours of the country traversed rather than attempting a straight line with heavy work.

Levels are taken and checked on the top of each chain peg. At the same time cross sections are taken to the full limits of the right of way, at each chain peg and where necessary between those points. No slope stakes are set however. When a contractor is awarded a contract, he is given a tracing of the permanent plan and section and must set cross section stakes where needed from the information thereon.

The referring of points is left entirely to the judgment of the instrument man and he uses the various known methods as best suit the locality.

Purchase of land for railway purposes is a comparatively small item in Cape Colony. Often the land is so cheap (\$1.50 to \$15.00 per acre) in comparison to the inhabitants' need of the railway, that farmers though whose property the line is projected, are willing to grant free right of way in exchange for the promise of a nearby station, cattle passes and crossings,

or other conveniences. The usual width of right of way is 33 feet on each side of the center line of railway. This narrow width necessitates of course much purchasing of extra land in cases of heavy work.

Moreover, an accredited land surveyor who has passed the Cape University Surveyors' examinations must survey and plot the land taken from each farm, placing a corner stone at each angle point. The charges for this seemingly unnecessary work are exorbitant and must be born by the government. The practice is a relic of the dark ages of Boer supremacy. It often occurs that land worth \$1.50 per acre expropriated, while the survey costs amounted, on the same land, to \$15.00 an acre.

All earthworks of less height or depth than one foot are known as forming and are paid for at a certain contract price per lineal chain.

The Cape government usually lets contracts in "lump sums" for the building of lengths of line complete—the contractors to turn the railway over ready for operation within a certain time limit.

Skilled labor in South Africa is scarce. Likewise scrapers, graders and plows are high priced and not often used. Raw native labor and the pick, shovel and wheelbarrow are the tools at the contractor's command. Arch culverts and the abutments of open culverts, the piers and abutments of bridges, cisterns, foundations, door steps and platform curbs are constructed of concrete.

Best imported Hamburg Portland cement, clean, sharp quartz sand, its particles varying from fine to coarse, and either clean gravel or stone broken to pass a 2 inch ring, mixed in the ratio 1: 3: 6 are the ingredients of the concrete used. The amount of water employed in mixing these ingredients is regulated to give the concrete, after tamping in the frame a jelly like consistency, without being sloppy. The concrete is mixed by hand unless needed in very large quantities, and the most important factor in this work is thorough, constant and competent supervision.

A most difficult problem in Cape Colonial railway engineering practice is drainage. The sudden cloud-bursts that occur during the rainy season give rise to floods that are very hard to control. Consequently large knowledge of watersheds and rainfall is necessary to the design of properly proportioned bridges and culverts.

During a survey of the Gauritz River gorge, it became necessary to place the line at an elevation above the half dry river bed of some ninety feet to be well above the high water marks, which showed unmistakably at 75 to 80 feet elevation. We may often see a steel bridge of four 100 feet spans built over a dry stream bed, at a height of some fifteen feet in the summer season, become with its approaches the only crossing for miles of a river more than bank full and more than 1000 feet wide. It is not the mere volume, but the first fierce onslaught of a great yellow wall of water, rushing down with wonderful force, carrying trees, boulders, everything moveable before it, that must be guarded against.

For bottom or sub-ballast there is required, six inches of the best obtainable ballast of gravel or stone broken to pass a 3-inch ring and three inches of top ballast broken to pass a 2-inch ring.

The road bed varies from 12 to 16 feet in width on banks and from 20 to 22 feet in cuts, according to specifications. The ties are of the dense Australian jarrah wood with holes ready bored for spikes. The ties are 5 inches x 10 inches x 7 feet and are very lasting. Rails are from 46 to 90 pounds weight per lineal yard. Fish plates are used to correspond with the weights of rails.

Grade posts carrying boards printed and slanted to indicate the grade and its inclination are placed at the various changes of grade. The mile posts carry iron disks on which the mileage is painted.

Station buildings and depots are of brick, of stucco covered adobe, or of corrugated iron sheeting lined with brick or adobe. The roofs are either of tile or corrugated iron. Wooden shingles are unknown and all wood is very expen-

sive, almost prohibitive in price. Concrete is very largely used instead of masonry.

Fences are of smooth wire passing through bored holes in lengths of old rails, serving as fence posts. Such fence gives splendid satisfaction. Telegraph poles are of iron. Wood is objectionable on account of the ravages of boring insects, notably the white ant. Fence posts and telegraph poles are often imbedded at their bases in concrete foundations.

As a result of much discussion in the Cape Parliament by unprofessional but well meaning persons, aided by some professional seekers after notoriety and public favor as economists, a line of railway of 2 feet gauge, with sharp curves and narrow road bed, is in process of construction between Port Elizabeth and Humansdorp. When we realize that this line is not a mere unimportant branch, but will at some future time be a portion of the great coast line of railway from Cape Town to Durban, the enormity of the crime committed by these advocates of toy railways becomes immediately apparent.

It seems reasonable that the cheapest gauge for Cape Colony is the 3' 6" standard. To widen it would be to upset the calculations on which all construction has been based for years past. It would call for an immediate retirement of existing rolling stock to a large degree, and for a corresponding expenditure for new stock, besides the relaying of track, widening of road bed and in many cases, renewing of both ties and rails. In short, a widening of gauge would call for an expenditure out of all proportions to the benefit resulting.

To reduce the whole system to a less gauge than the present standard would be like trading a good article and much additional cash for an article inferior to the first.

But to add to a growing system of certain well tried gauge, a few hundred miles of a less gauge as a portion of a main line is too great a folly, to admit of a metaphor. There is little doubt that this first experiment will not be repeated, even in Cape Colony.